MACHAKOS UNIVERSITY

University Examinations 2022/2023

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

SECOND YEAR SECOND SEMESTER EXAMINATIONS FOR

BACHELOR OF SCIENCE (TELECOMMUNICATIONS AND INFORMATION TECHNOLOGY)
BACHELOR OF SCIENCE (ANALYTICAL CHEMISTRY)

BACHELOR OF EDUCATION (SPECIAL NEEDS)

BACHELOR OF SCIENCE (MATHEMATICS)

BACHELOR OF EDUCATION (SCIENCE)

SCH 203: THEORY OF SPECTROSCOPIC METHODS

DATE: 14/4/2023 **TIME: 8:30 – 10:30 AM**

INSTRUCTIONS:

i) The paper consists of **TWO** sections, section **A** and section **B**.
ii) Section **A** is **compulsory** (30 marks).
iii) Answer any **two** questions from section **B** (each 20 marks).

Given that, B = $\frac{h}{8\pi^2\ Ic}$ and I = μr_o^2, J_{max} = $\sqrt{\frac{kT}{2Bhc}} - \frac{1}{2}$, where h = 6.626 × 10^{-34}Js, velocity of light, c = 2.998 x 10^8 m/s, Boltzmann constant, k = 1.38 x 10^{-23} J/K, Avogadros constant, L = 6.023 x 10^{23} particles and π = 3.14, $k = 4\pi^2 c^2 \mu \bar{\omega}_e^2$ where k is Force constant, 1Js = 1 Kgm^2s^{-1}, 1N/m = $10^3 g/s^2$.

SECTION A (COMPULSORY)
QUESTION ONE (30 MARKS)

a) **Define** the following terms, indicating their **symbols** and stating their **SI units**. (6 marks)

(i) Frequency

(ii) Velocity

(iii) Bond length

b) Draw a well labelled electromagnetic radiation spectrum showing all the seven spectra. (5 marks)

c) The green light at the Visible spectrum region is observed at 550 nm while the Gamma Rays take effect at 10^{-6} nm. Convert (3 marks)

(i) 550 nm to cm

(ii) 10^{-6} nm to meters

d) The visible yellow colour, has a frequency of 4.65 x 10^{14} Hz, calculate the corresponding

(i) Wavelength in nm (3 marks)

(ii) Wavenumber (2 marks)

(iii)Energy of the radiation (2 marks)

e) The total energy of a molecule is the sum of translational, rotational, vibrational and electronic energies.The transitions of energies can take place only between the three quantized energy levels of a molecule resulting to a molecular spectrum. Sketch these energy levels for a molecule with two electronic energy levels and clearly label them. (5 marks)

f) According to the Boltzmann distribution law, the ratio of the number of molecules present in two energy states can be given by the equation:

$$\frac{N_J}{N_o} = e^{-[\frac{Bhc J(J+1)}{kT}]}$$

In this equation, state and explain the effect on the ratio $\frac{N_J}{N_o}$ when

(i) J value is increased (2 marks)

(ii) T value is increased (2 marks)

SECTION B (ANSWER ANY TWO QUESTIONS)

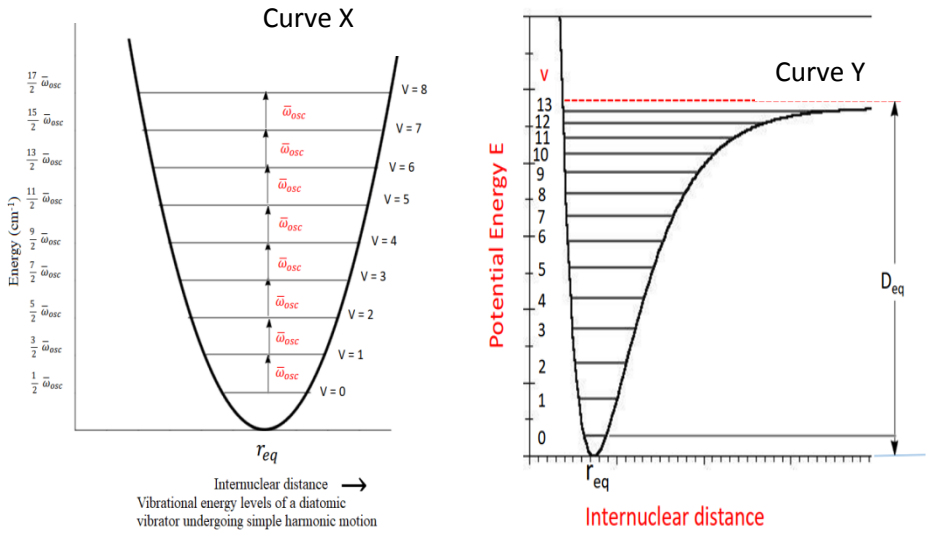
QUESTION TWO (20 MARKS)

a) Differentiate between the following terms as used in Spectroscopic chemistry.

(i) Rayleigh scattering and Raman scattering as used in Raman spectra (2 marks)

(ii) Stokes' radiation and Anti-stokes' radiation. (2 marks)

b) By using the following potential energy curve diagrams, answer the following questions:



(i) Identify the Morse curve and the Harmonic curve (2 marks)

(ii) List any four characteristics of each function. (Curve X and Curve Y) (8 marks)

c) Spectroscopic instruments are widely applied in laboratory analytical instrumentation both in research and industrial institutions. Describe any three applications of Infra-Red spectroscopy. (6 marks)

QUESTION THREE (20 MARKS)

a) When an intense beam of light is passed through a transparent medium, some of the light is scattered as a characteristic of the molecules of the medium. Describe the two possible types of scattering that can be observed. (5 marks)

b) (i) Define the term Raman shift as used in Raman spectroscopy. (2 marks)

(ii) Differentiate between fundamental and overtone transitions as used in Raman Spectroscopy. (4 marks)

c) Explain the following terms as used in Spectroscopic techniques

i) Anti-stokes' radiation (1½ marks)

ii) Electromagnetic radiation (1½ marks)

iii) Moment of inertia (1½ marks)

iv) Selection rule of transition (1½ marks)

v) Degrees of freedom (1½ marks)

vi) Inelastic collision (1½ marks)

QUESTION FOUR (20 MARKS)

a) The fundamental and first overtone transitions of $^{14}N^{16}O$ are centred at 1876.06 cm^{-1} and 3724.20 cm^{-1}, respectively. Evaluate the equilibrium vibrational frequency, the anharmonicity constant and the force constant for the species. (10 marks)

b) Using an example in each case, briefly explain how the concept of fluorescence, phosphorescence and chemiluminescence works under photo physical processes. (10 marks)

QUESTION FIVE (20 MARKS)

a) Considering the molecular vibrations of carbon dioxide, CO_2, with respect to symmetric and asymmetric stretch as well as in plane and out of plane bending, show whether or not these vibrations result to an Infra-Red active mode for CO_2 molecule. (8 marks)

b) (i) The first rotational line in the rotational spectrum of CO is observed at 3.84235 cm^{-1}.

Calculate its rotational constant, B, moment of inertia, I, and the bond length, r_0.

(8 marks)

(ii) Determine the J value of the rotational level for CO with maximum population at

30 °C? (Given that $J_{max} = \sqrt{\frac{kT}{2Bhc}} - \frac{1}{2}$) (4 marks)